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US Army Research Laboratory

A Comparison of Antenna Measurements in a Near-Field Range and a Newly Renovated Short-Tapered Chamber

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14. ABSTRACT

This study was undertaken to quantify and compare electromagnetic device (i.e., antenna) measurements using the US Army Research Laboratory's (ARL) near-field range (NFR) and tapered anechoic chamber, which has been newly renovated with absorber material. ARL would like to know the performance levels with the NFR and the newly renovated, slightly different absorber layout configuration laid out and designed by the contractor. Post-renovation measurements in the tapered chamber led to a further reconfiguration of the absorber near the apex. This second post-renovation reconfiguration resulted in a slight performance improvement over the initial post-renovation, but not as broadband as the pre-renovation data.

15. SUBJECT TERMS

electromagnetic, chamber, near-field range, anechoic chamber, antenna measurement

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1. Introduction

This study was undertaken to quantify and compare electromagnetic (EM) device (i.e., antenna) measurements using the US Army Research Laboratory's (ARL's) near-field range (NFR) and tapered anechoic chamber. The NFR and tapered anechoic chamber are the basic resources that the antenna team can use to measure and characterize EM fields that are transmitted and/or received by devices (e.g., antennas) to validate simulated performance with measured data. Accordingly, it is imperative that the NFR and tapered anechoic chamber be assessed using a standard antenna to determine any discrepancies in our measurement capabilities.

The NFR can obtain planar, cylindrical, or spherical near-field measurements of EM fields, while the tapered anechoic chamber can obtain spherical far-field pattern measurements of EM fields. Our NFR has a frequency range of 1.2–50 GHz with maximum internal chamber dimensions of 25 × 16 × 10 ft, while the tapered anechoic chamber has a frequency range of 0.2 –50 GHz with chamber dimensions of 20 × 20 × 55 ft.

2. Antenna Under Test (AUT)

To quantify any measurement discrepancies between the NFR and the tapered anechoic chamber, a Schwarzbeck BBHA-9120-D[1] antenna (Fig. 1) was selected as the standard antenna under test (AUT). This antenna is operational from 1 to 18 GHz and has a calibrated gain of 6.3–18 dBi available from the manufacturer. A large swath of data was collected on this AUT in the tapered chamber and the NFR for purposes of comparison.

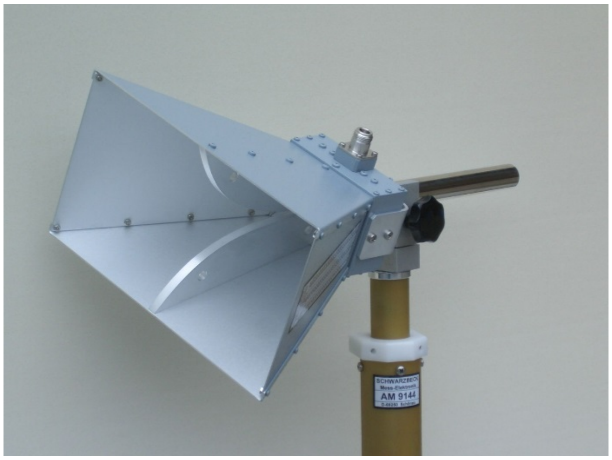

Fig. 1 BBHA-9120-D antenna (image provided by Schwarzbeck Mess-Elektronik[1])

3. Antenna Theory

For the purposes of testing in the NFR, the antenna must be situated in the radiating near-field for proper data acquisition. The antenna has a reactive near-field from 0 to λ with a fairly flat field distribution, where objects in this region can possibly cause unwanted coupling to the antenna. As such, near-field systems cannot measure inside this region due to the unknown coupling effects to an AUT. The radiating near-field is from λ to $2D^2/\lambda$ with a fairly smooth field distribution, where D is the largest dimension across the aperture.[3] Near-field systems measure inside this region. The far-field region is next, extending beyond $2D^2/\lambda$, where most antenna chamber measurements are done. Figure 2 shows the fields from a radiating antenna.

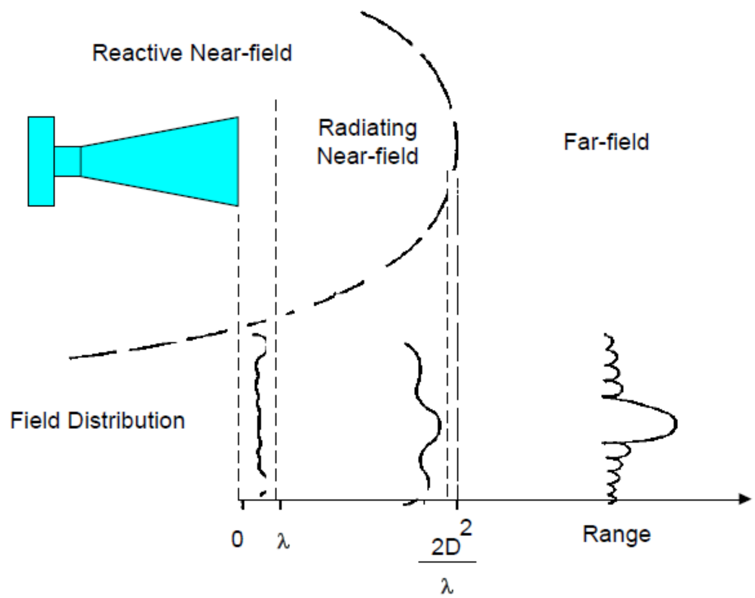

Fig. 2 Fields from a radiating antenna (image provided by Nearfield Systems, Inc.[2])

The theory behind near-field measurements was developed at the National Institute of Science and Technology (NIST) in the 1970s by the Technical University of Denmark and NIST. NIST has validated the mathematical calculation of far-field patterns based on amplitude and phase samples in the radiating near-field.

4. Near-Field Range (NFR)

The near-field planar measurement system is best suited for characterizing highly directive antennas or arrays, since less than a hemisphere (spanning 180° × 180°) of energy can be measured with a planar scan. The AUT is positioned 3–5 wavelengths away from the planar scanner hampering any wideband characterization without relocating the AUT. In addition, the hemisphere transitions to a narrower cone measurement as the test frequency lowers, thereby reducing the angular span of the measurement. The planar NFR uses waveguide probe antennas (7 antennas cover 1.1–18 GHz) with no AUT slide or removable mast and can measure mid- and small-sized AUTs. A single planar scan requires about an hour of acquisition time for each waveguide probe measurement. No 2-D far-field patterns can be produced until a full planar near-field measurement is completed.

The near-field spherical measurement system can be used for characterizing antennas or arrays and can measure EM fields spanning 330° × 180° of a sphere on a single setup. For this measurement, the AUT should be placed above the azimuth positioner's center of rotation while centered along the phi positioner's center of rotation. The spherical NFR uses waveguide probe antennas (7 antennas cover 1.1–18 GHz) with no AUT slide or removable mast, and can measure mid- and small-sized AUTs. A single spherical scan can require 2–72 h depending on wavelength and antenna positioning. Two-dimensional far-field patterns cannot be produced until a full spherical near-field measurement is completed. Therefore, spherical near-field measurements are better than planar for this comparison study with the tapered anechoic chamber. The data needed from the NFR for this report took a couple of days to collect with the spherical near-field.

Figures 3–5 represent a very small fraction of the data taken in the NFR, but they are presented here to show the NFR's capability to capture an AUT's pattern characteristics over a wide frequency range.

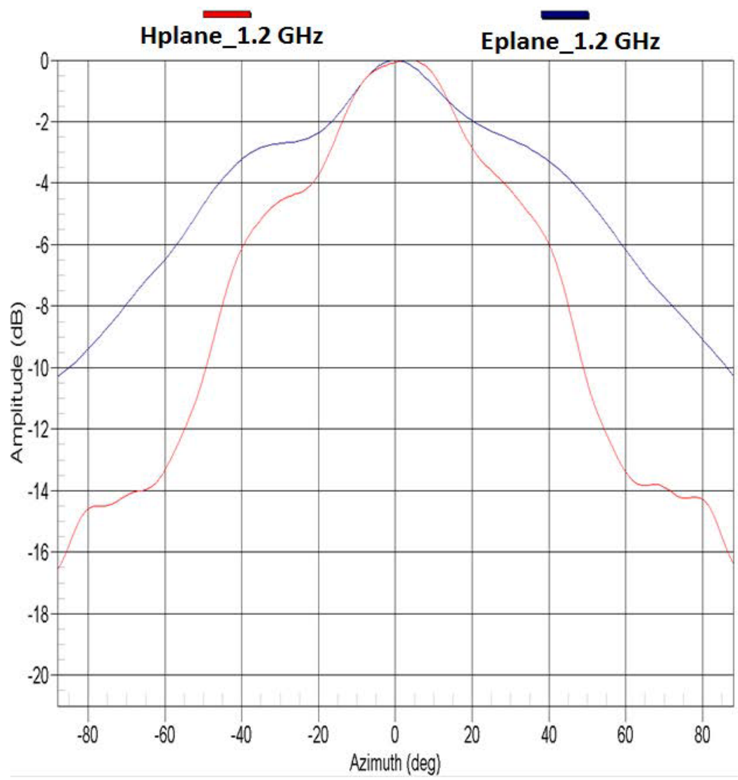

Fig. 3 Far-field E- and H-plane antenna patterns at 1.2 GHz with spherical near-field data

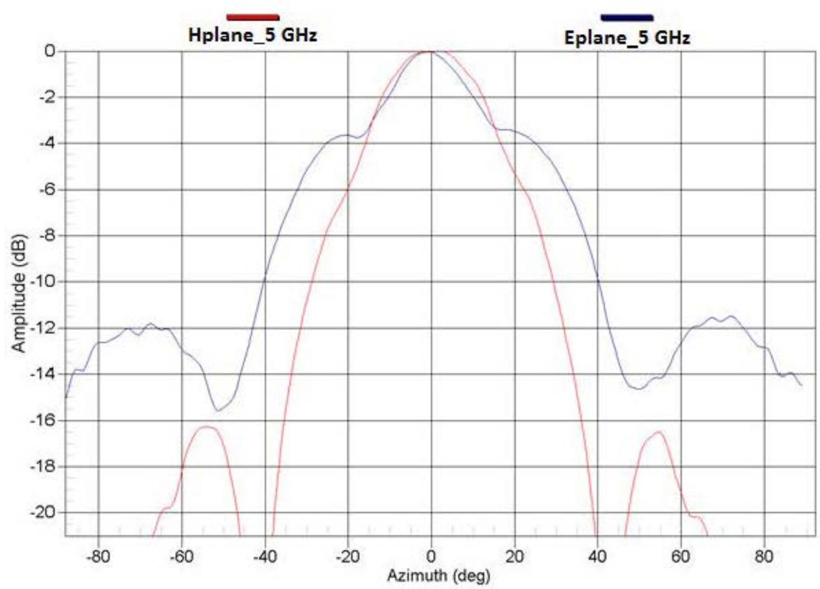

Fig. 4 Far-field E- and H-plane antenna patterns at 5 GHz with spherical near-field data

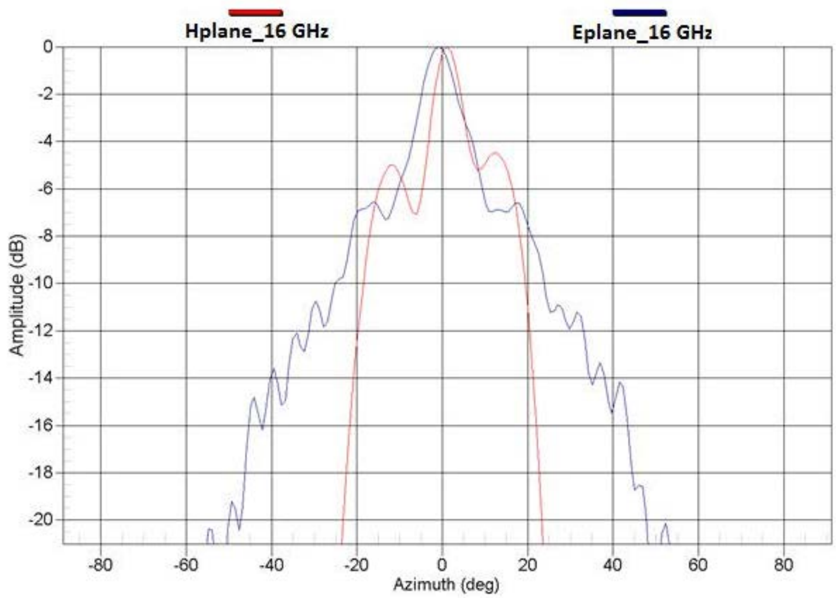

Fig. 5 Far-field E- and H-plane antenna patterns at 16 GHz with spherical near-field data

5. Tapered Anechoic Chamber or Far-Field Range (FFR)

ARL's tapered anechoic chamber spherical measurement system can be used for characterizing antennas or arrays, and can measure EM fields spanning 360° × 180° of a sphere. It can measure a single point to determine realized gain, angular sweeps for 2-D pattern cuts, circular polarization, and 3-D patterns. The AUT should be placed above the azimuth positioner's center of rotation while centered along the phi positioner's center of rotation. The chamber uses decade calibration antennas (2 antennas cover 0.2–18 GHz) and has an AUT slide with removable mast allowing measurement of large and small AUTs. A single 3-D spherical scan will take 3 h for 1–18 GHz, but a 2-D cut plane takes about 5 min.

Figures 6–8 represents a very small fraction of the data taken in the tapered chamber, the far-field range (FFR), but they are presented here to show the tapered chamber's capability to capture an AUT's pattern characteristics over a wide frequency range.

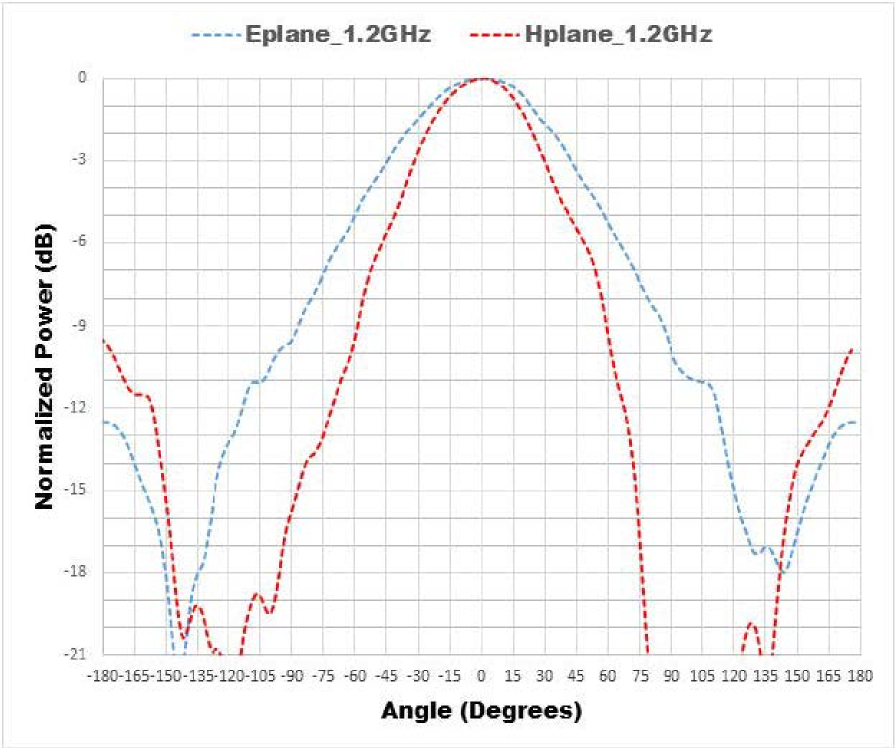

Fig. 6 E- and H-plane antenna patterns at 1.2 GHz with spherical far-field data

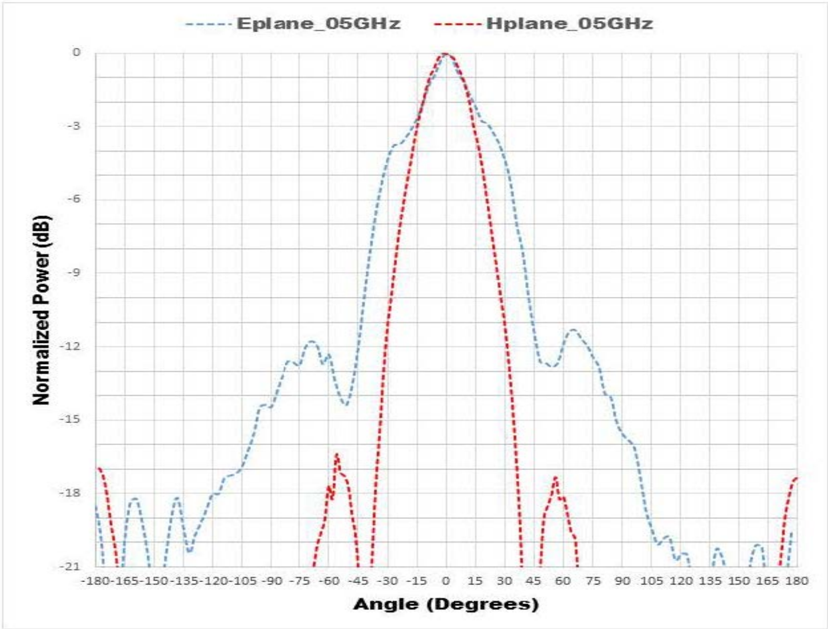

Fig. 7 E- and H-plane antenna patterns at 5 GHz with spherical far-field data

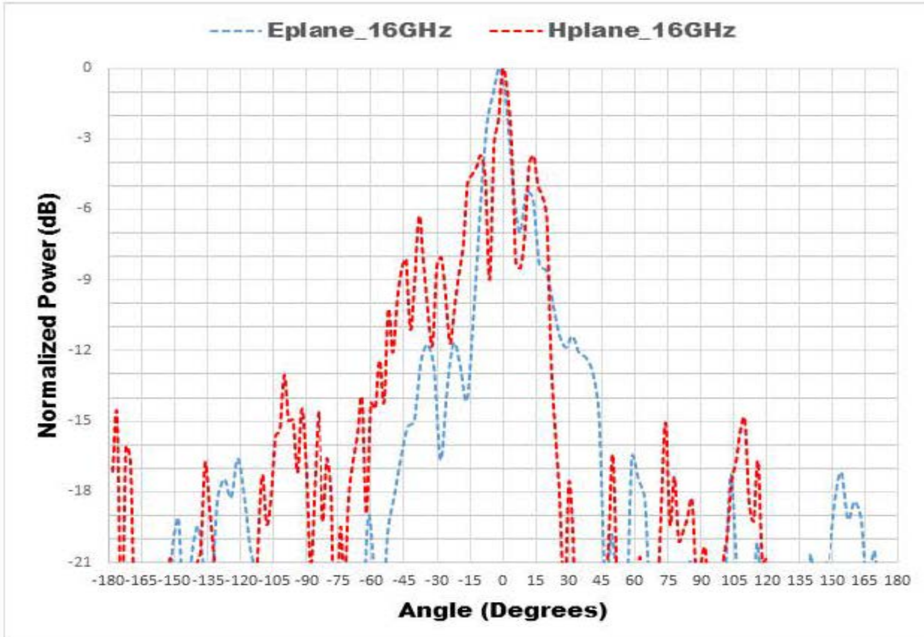

Fig. 8 E- and H-plane antenna patterns at 16 GHz with spherical far-field data

6. Comparison

The FFR are the dashed lines and the red lines are the H-planes in Figs. 9–11. The 1.2-GHz E- and H-plane patterns show similar pattern shapes and levels. One characteristic that helps to describe an antenna is its 3-dB beamwidth. A more in-depth comparison characterization is provided in Tables 1–3. The measurements at 1.2 GHz are fairly close to each other and can be explained by the NFR being at the edge of specifications for this measurement. The E-plane patterns (blue) at 5 GHz overlap well, even capturing sidelobe locations and levels, with negligibly different 3-dB E-plane beamwidths. At 16 GHz, they share a very similar 3-dB beamwidth and pattern over that characteristic beamwidth. The FFR H-plane return in Fig. 11 is higher on the left side due to ceiling absorber dangling down on that side.

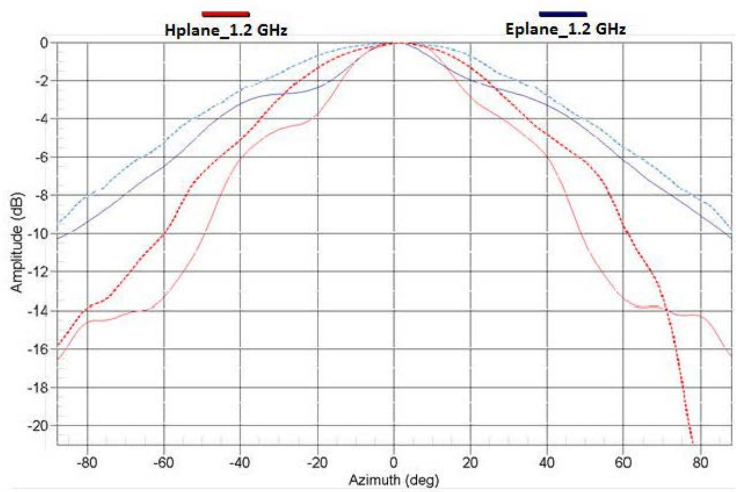

Fig. 9 E- and H-plane antenna patterns at 1.2 GHz from the FFR and NFR

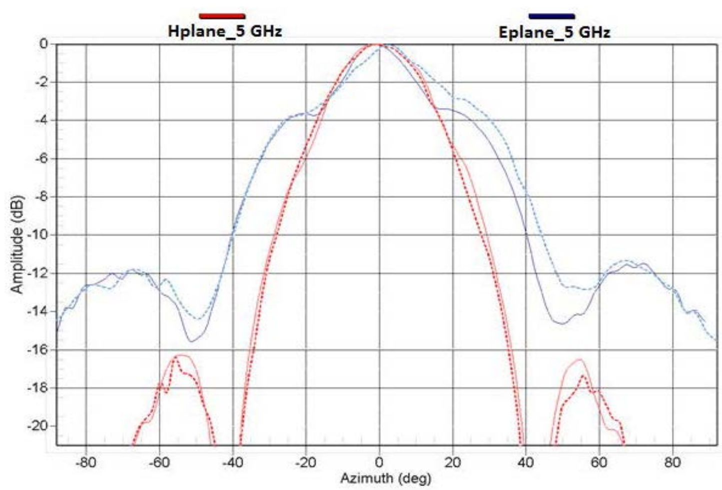

Fig. 10 E- and H-plane antenna patterns at 5 GHz from the FFR and NFR

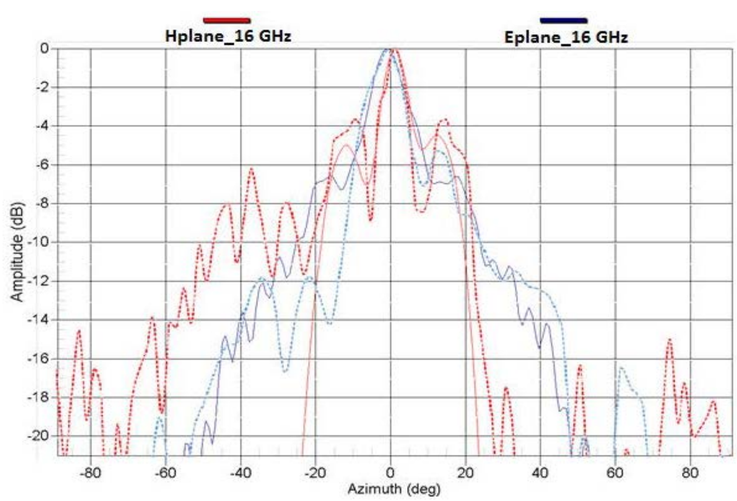

Fig. 11 E- and H-plane antenna patterns at 16 GHz from the FFR and NFR

Table 1 E- and H-plane beamwidths at 1.2 GHz from the FFR and NFR

Beamwidth	NFR H-plane	FFR H-plane	NFR E-plane	FFR E-plane
3 dB	38°	60°	80°	88°
6 dB	80°	105°	117°	130°
9 dB	95°	115°	157°	170°
12 dB	110°	135°		

Table 2 E- and H-plane beamwidths at 5 GHz from the FFR and NFR

Beamwidth	NFR H-plane	FFR H-plane	NFR E-plane	FFR E-plane
3 dB	27.5°	27.5°	27.5°	37.5°
6 dB	41.0°	41.0°	63.5°	67.0°
9 dB	53.5°	51.5°	75.5°	78.5°
12 dB	62.0°	60.5°	84.0°	89.5°

Table 3 E- and H-plane beamwidths at 16 GHz from the FFR and NFR

Beamwidth	NFR H-plane	FFR H-plane	NFR E-plane	FFR E-plane
3 dB	7.5°	7.5°	10.5°	10.5°

Overall, these results are consistent with NIST's validation of near-field to far-field transformations, and will overlay better when the FFR ceiling absorber is fixed.

7. Conclusion

This study was motivated to further validate our EM device measurements. Both systems measure patterns well, but each system has its own unique capabilities. Pattern and gain measurements are done quickest over a wide frequency range in the tapered anechoic chamber. The tapered anechoic chamber can also be used to find an antenna's phase centers. The NFR is best suited to produce far-field patterns from measured near-fields of antenna arrays and finding EM leakage with its NSI software tools. ARL's planar near-field measurement system requires the AUT to have a gain greater than 15 dBi, while a spherical near-field measurement only requires the AUT minimize radiation toward the phi positioner's metal mounting plate.

This study has proven that the tapered anechoic chamber and NFR do provide comparable results, which will further validate our EM device measurements. A follow-on report will further quantify the differences between the 2 chambers.

8. References

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3. Balanis Constantine A. Antenna theory: analysis and design. Hoboken (NJ): Wiley Interscience; 2005. p. 167–170.

List of Symbols, Abbreviations, and Acronyms

2-D	2-dimensional
3-D	3-dimensional
ARL	US Army Research Laboratory
AUT	antenna under test
EM	electromagnetic
FFR	far-field range
NFR	near-field range
NIST	National Institute of Science and Technology

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